Fermi National Accelerator Laboratory

FERMILAB-Conf-93/146-E

CDF

Direct Photon Results from CDF

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June 1993

Published Proceedings *XXVIIIth Rencontres de Moriond, QCD and High Energy Hadronic Interactions*, Les Arcs, Savoie, France, March 20-27, 1993

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CDF/PUB/JET/PUBLIC/2103
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DIRECT PHOTON RESULTS FROM CDF

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Abstract

Results using photons measured with the CDF detector during the 1992-93 run of the Fermilab Tevatron are presented. Photon detection and background suppression are described. Measurement of the inclusive photon cross section as well as photon-jet cross sections are discussed and compared to next-to-leading order QCD predictions. The search for excited quarks using the photon-jet mass distribution is described and a limit is derived.

*Supported by the U.S. Dept. of Energy, contract number DE-AC02-76CH03000.

Published Proceedings XXVIIth Rencontres de Moriond, High Energy Hadronic Interactions, Les Arcs, Savoie, France, March 22, 1993.

INTRODUCTION

Photons produced directly from the hard collision provide a probe of the gluon structure functions and an energy measurement which is free from the effects of fragmentation. This paper presents a brief summary of prompt photon results using the CDF detector[1] and data collected during the 1992-1993 running of the Fermilab proton-antiproton collider.

Photons are identified in the CDF detector by the presence of an isolated highly electromagnetic cluster which has no associated charged tracks[2]. The main background is dijet events in which one of the jets has fragmented into a single π^0. While the probability for this fragmentation is quite low, the dijet cross section is much larger than the prompt photon cross section and at CDF energies the mix of signal to BKG is roughly 1:1.

A shower profile method and a conversion method are employed for separation of photons from the background. In particular, between 1989 and 1992 a new conversion detector was installed and has greatly improved photon-background separation at high P_T . In addition, a neural net isolation requirement is now made at the trigger level. These improvements have resulted in increased statistics and better photon-background rejection than in 1989. The isolated inclusive photon cross section now spans over 6 orders of magnitude with less than half of the 1992-93 data analyzed. The low x behavior of the gluon structure function is probed by measuring the photon-jet cross section. A search for excited quarks has been undertaken using both the 1988-89 and 1992-93 data samples and limits on the cross section and mass have been set.

PHOTON IDENTIFICATION

CDF has two statistical methods for separation of photons from the background. The shower profile method is based on the shower shape of the electromagnetic clusters as measured in the Central Electromagnetic calorimeter Strip chambers (CES) which are embedded in the Central Electromagnetic Calorimeter (CEM) at approximately shower maximum (5.9 radiation lengths). The conversion method relies on the relative conversion probabilities of the photons and background. Between the 1989 and 1992 runs of the Tevatron, the Central PreRadiator multiwire proportional chambers (CPR) were installed outside the 1.09 radiation lengths of material in the CDF solenoid, just in front of the CEM calorimeter.

The shower profile technique is described in detail in reference [2]. The fundamental criteria is a χ^2 comparison of the shower shape as measured in the CES to that of single electrons. While prompt photon events produce a χ^2 distribution which peaks below 4, π^0s produce a broad χ^2 distribution. The efficiency of a cut of $\chi^2 < 4.0$ is determined for true photons, ϵ_γ, and for the background, ϵ_B, as a function of P_T using Monte Carlo simulations and test beam electrons. The fraction of photons is calculated using these efficiencies:

$$F_\gamma = \frac{\epsilon_B - \epsilon}{\epsilon_B - \epsilon_\gamma},$$

where ϵ is the fraction of events in the data with $\chi^2 < 4$. Figure 1a shows the efficiencies for the shower profile method for the 1989 and 1992 data. This method can only be used

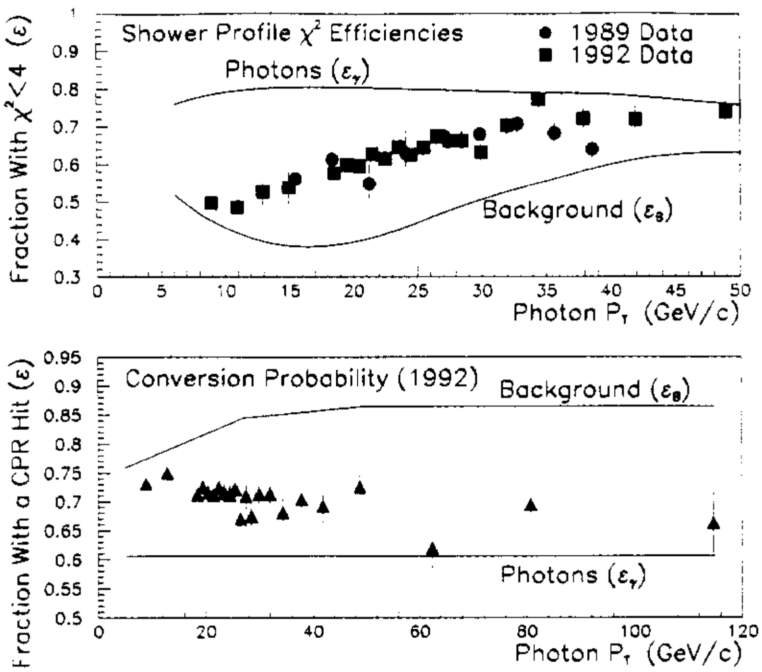

Figure 1: Photon Background Subtraction

for $P_T < 40$ GeV. As the P_T of the π^0 increases, the two clusters from the π^0 decay become indistinguishable.

The conversion method is roughly independent of P_T and thus allows measurement of the inclusive photon cross section over a wide P_T range. This method simply looks for the presence of hits in the CPR detector. Because a π^0 decays to two photons, it is more likely to produce a conversion which will be measured in the CPR. Figure 1b shows the conversion probability for photons and π^0's as predicted by the Monte Carlo and as measured in the data. Note that the curves are flat above P_T =25 GeV and that the P_T range shown for this data extends to 120 GeV. At present, the P_T independent systematic uncertainty for the CPR method is ≈20%, with a P_T dependent systematic uncertainty of ≈ 10%. As further refinements are incorporated these are expected to be reduced to ≈ 10% and ≈ 5% respectively.

TRIGGER and DATA SAMPLE

The bulk of the photon data has been collected using thresholds on the photon P_T of 6 (prescaled) and 16 GeV, and a neural net trigger which makes a loose isolation requirement. For high P_T , a threshold of P_T >70 GeV is used and no isolation requirements are made.

In the offline analysis, an isolation requirement of < 2 GeV in a cone of radius 0.7 around the photon is made. The data analysis cuts are identical to the cuts described in reference [2] with the exception of the no track requirement which now extends to a slightly wider range in rapidity. The total integrated luminosity is $\approx 3.2pb^{-1}$ below a P_T of 70 GeV; above 70 GeV roughly $9.7pb^{-1}$ has been analyzed.

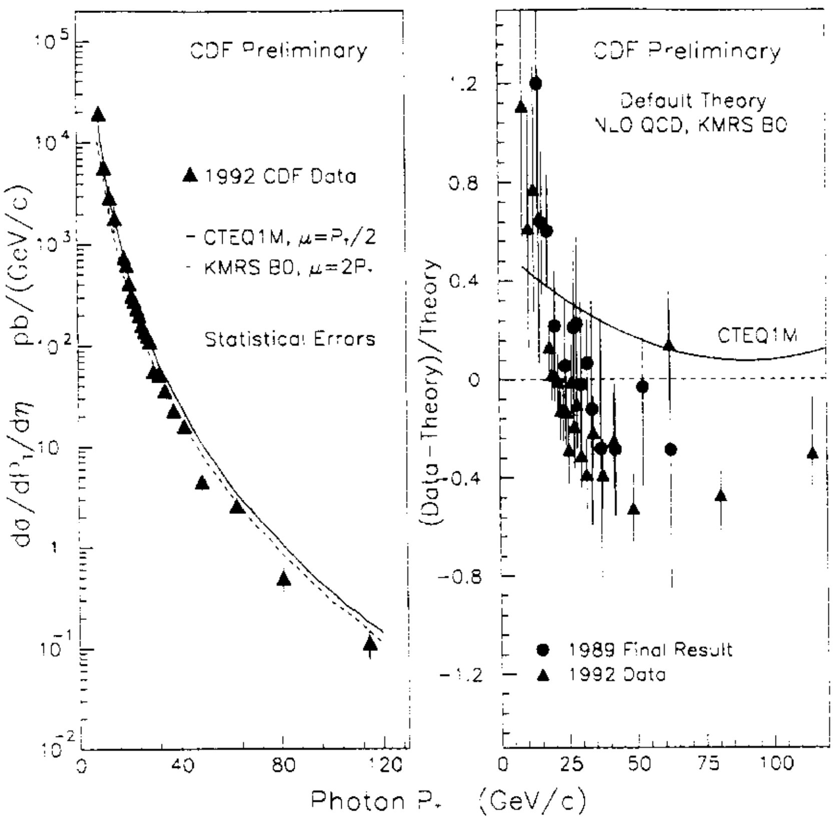

Figure 2: Inclusive photon cross section

INCLUSIVE PHOTON CROSS SECTION

The inclusive photon cross section has been measured using both the shower profile method and the conversion method. The results are in good agreement in the region of over lap and are also in good agreement with the measured 1988-89 photon cross section. Figure 2 shows the prompt photon cross section as measured by CDF using the 1992-93 data sample. Note that the measurement now extends from 8 GeV to 120 GeV in P_T . For this measurement the CPR method is used above P_T =16 GeV and the CES method has been used for the range $8 < P_T < 16$ GeV. Also shown in Figure 2 is the cross section on a linear scale, compared to two next-to-leading order theoretical curves and to the final result from the 1988-89 data. Note the difference in shape at low P_T between the CTEQ1M structure function and KMRSB0, and that neither provide a good description of the data. The effect of higher order terms, bremsstrahlung diagrams and new structure functions are under study.

PHOTON-JET CROSS SECTION

The gluon distribution function is expected to dominate in low x interactions. The rapidities of the photon and jet are related to x by the equation:

$$x_{1(2)} = \frac{P_T}{\sqrt{s}}(e^{(-)\eta_{jet}} + e^{(-)\eta_\gamma})$$

For a central photon of P_T =7 GeV and a central jet , x1=x2≈0.008, while for a central photon and a jet in the range $1.4 < |\eta_{jet}| < 2.2$, $x_1 \approx 0.02$ and $x_2 \approx 0.004$. By measuring the cross section for different photon and jet rapidities, a wide range of x can be probed.

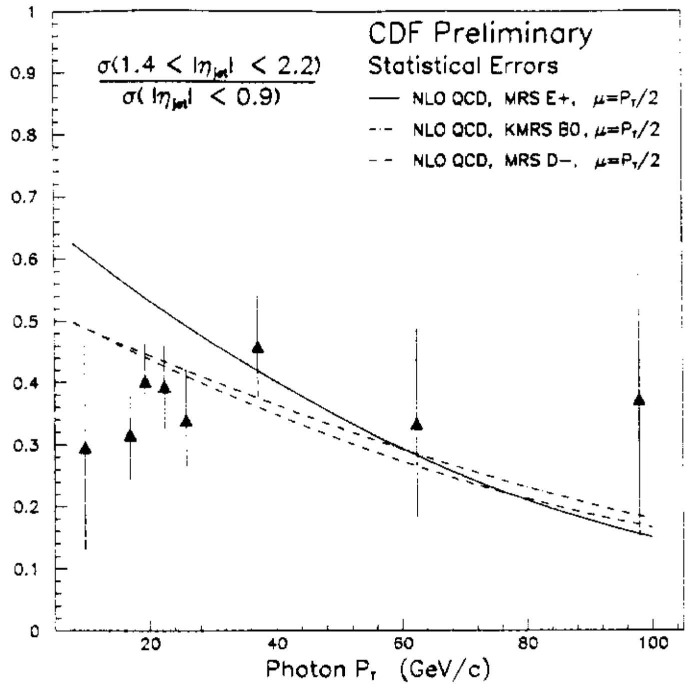

Figure 3: Ratio of photon-jet cross sections for different jet rapidity regions.

Figure 3 shows the ratio of the photon-jet cross sections for the case were the jet is restricted to the region $1.4 < |\eta_{jet}| < 2.2$ to the case where the jet is restricted to the central region $|\eta_{jet}| < 0.9$. Theoretical predictions for three sets of parton distribution functions are shown. With the full statistics of the 1992-1993 run, the CDF measurement will be able to provide important information about the behavior of the parton distribution functions at low and high values of x.

PHOTON-JET MASS: EXCITED QUARKS?

Excited or composite quarks could produce a resonance in the photon-jet mass distribution. Predictions for branching ratios and cross sections[3] indicate that if such a resonance existed it would be obvious in the CDF data. This analysis uses the 1992-93 photon data for $P_T > 70$ GeV and below 70 GeV the 1988-89 data sample is used. In addition to the photon cuts described above, a jet is required in the event with $|\eta| < 2.0$. The mass is defined in terms of the photon energy to avoid the resolution smearing effects associated with the jet energy measurement: $M = 2P_{T\gamma}cosh\eta^*$, where $\eta^* = (\eta_\gamma - \eta_{jet})/2$. To reduce the QCD background, a cut on $\eta^* < 0.8$ is made. In contrast to the previously described analyses, the shower profile and conversion methods are not used to remove the background.

To search for the presence of an excited quark resonance, a binned maximum likelihood fit is used. The differential cross section at a given mass is calculated from the theory and smeared by the mass resolution. Generation of a true background spectrum (a combination of the photon spectrum and the dijet spectrum where one of the jets fragments into a π^0) is difficult at best and fraught with many uncertainties. To avoid these problems, a simple power law parameterization is used to estimate the amount of background in each bin. The data is fit to the combination of the power law parameterization and an excited quark

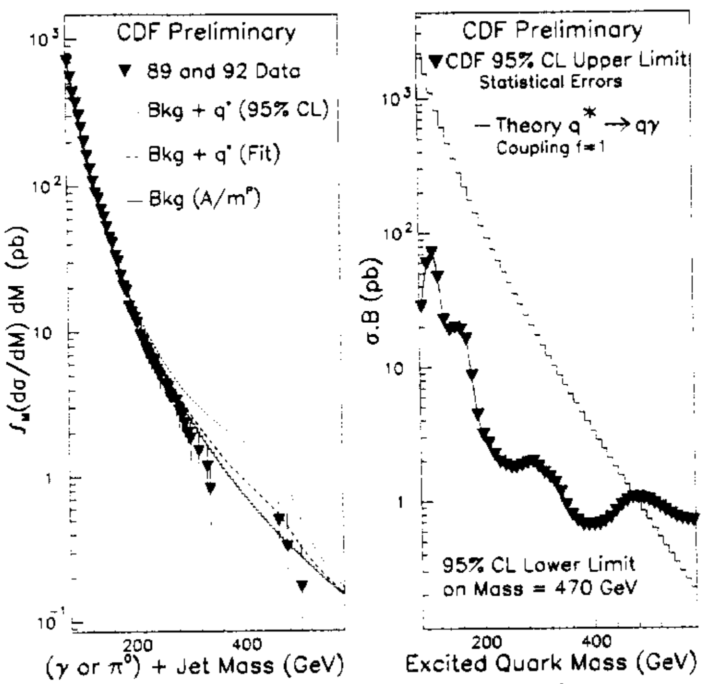

Figure 4: Photon-Jet mass integral spectrum and limit on excited quark mass.

resonance. A 95% confidence level on the upper limit of the excited quark cross section is then derived for each value of photon-jet mass. Figure 4a shows the data compared to the background and to curves including an excited quark. Figure 4b shows the limit on $\sigma * B$ as a function of excited quark mass compared to an excited quark theory in which the coupling f=1. The place where the curves intersect determines the lower limit on the excited quark mass. For this data, and including only statistical uncertainties, a limit of 470 GeV is derived.

CONCLUSIONS

With only a fraction of the expected data of the 1993-93 run analyzed, CDF has already been able to investigate the low x behavior of the structure functions, to greatly extend the P_T range of the inclusive photon cross section measurement and to set new limits on the presence of excited quarks.

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